CLAIMS

1. In a clock data recovery system including a voltage controlled oscillator (VCO) and a phase/frequency detector (PFD), a method for synchronizing a reference clock to a pseudorandom non-return to zero (NRZ) data stream, the method comprising:

sampling a pseudorandom NRZ data stream;

determining a mean frequency of transitions (Fd) in the data stream;

determining a transition probability (P) associated with the mean frequency of transitions;

using a phase/frequency detector (PFD) responsive to a VCO frequency, the mean frequency of transitions, and the transition probability;

in response to using the phase/frequency detector, supplying a voltage controlled oscillator tuning voltage; and,

generating the VCO frequency responsive to the tuning voltage.

2. The method of claim 1 in which an exclusive-OR (XOR) phase detector is included, and the method further comprising:

after generating the VCO frequency, using a XOR phase detector to compare the VCO frequency to the NRZ data stream;

in response to using the XOR phase detector, supplying a voltage controlled oscillator tuning voltage; and,

generating the VCO frequency responsive to the tuning voltage.

3. The method of claim 2 further comprising:

deriving a mean data stream rate (B) from a comparison of the mean frequency of transitions and the transition probability, where B = Fd/P; and,

wherein using a phase/frequency detector responsive to a VCO frequency, the mean frequency of transitions, and the transition probability includes comparing the mean data stream rate to the VCO frequency.

4. The method of claim 2 further comprising:

multiplying the VCO frequency by P to supply a scaled VCO frequency; and,

wherein using a phase/frequency detector responsive to a VCO frequency, the mean frequency of transitions, and the transition probability includes comparing the scaled VCO frequency to the mean frequency of transitions.

5. The method of claim 2 wherein determining a mean frequency of transitions (Fd) in the data stream includes determining the frequency of transitions selected from the group including:

positive transitions having a 0.25 probability of occurrence;

negative transitions having a 0.25 probability of occurrence; and,

both positive and negative transitions having a 0.5 probability of occurrence.

6. The method of claim 5 wherein sampling a pseudorandom NRZ data stream includes sampling n data bits;

wherein determining a mean frequency of transitions (Fd) in the data stream includes determining a mean frequency of transitions with a standard deviation as follows:

$$\sigma = \mathrm{SQRT}((P)(1 - P)(n)).$$

7. In a clock data recovery system including a voltage controlled oscillator (VCO) and a phase/frequency detector (PFD), a method for synchronizing a reference clock to a pseudorandom non-return to zero (NRZ) data stream, the method comprising:

sampling a pseudorandom NRZ data stream;

determining a mean frequency of transitions (Fd) in the data stream;

determining a transition probability associated with the mean frequency of transitions;

accumulating a mean transition count (Np) of frequency transitions over a gate time period (Td);

supplying a compensated transition count (Nc), where Nc = Np/P;

establishing a plurality of VCO frequency ranges;

determining a frequency range corresponding to the compensated transition count;

operating the voltage controlled oscillator within the determined frequency range;

using a phase/frequency detector responsive to the VCO frequency, the mean frequency of transitions, and the transition probability;

in response to using the phase/frequency detector, supplying a voltage controlled oscillator tuning voltage; and,

generating the VCO frequency responsive to the tuning voltage.

8. The method of claim 7 in which an exclusive-OR (XOR) phase detector is included, and the method further comprising:

after generating the VCO frequency, using a XOR phase detector to compare the VCO frequency to the NRZ data stream;

in response to comparing, supplying a voltage controlled oscillator tuning voltage; and,

generating the VCO frequency responsive to the tuning voltage.

9. The method of claim 8 further comprising:

deriving a mean data stream rate (B) from a comparison of the mean frequency of transitions and the transition probability, where B = Fd/P; and,

wherein using a phase/frequency detector responsive to a VCO frequency, the mean frequency of transitions, and the transition probability includes comparing the mean data stream rate to the VCO frequency.

10. The method of claim 8 further comprising:

multiplying the VCO frequency by P to supply a scaled VCO frequency; and,

wherein using a phase/frequency detector responsive to a VCO frequency, the mean frequency of transitions, and the transition probability includes comparing the scaled VCO frequency to the mean frequency of transitions.

11. The method of claim 8 wherein determining a mean frequency of transitions (Fd) in the data stream includes determining the frequency of transitions selected from the group including:

positive transitions having a 0.25 probability of occurrence;

negative transitions having a 0.25 probability of occurrence; and,

both positive and negative transitions having a 0.5 probability of occurrence.

12. The method of claim 11 wherein sampling a pseudorandom NRZ data stream includes sampling *n* data bits; and,

wherein determining a mean frequency of transitions (Fd) in the data stream includes determining a mean frequency of transitions with a standard deviation as follows:

$$\sigma = \mathrm{SQRT}((P)(1 - P)(n)).$$

13. In a system including a clock data recovery (CDR) unit, a voltage controlled oscillator (VCO), a phase/frequency detector (PFD), and a reference frequency source, a method for generating a reference clock in the absence of a pseudorandom non-return to zero (NRZ) data stream, the method comprising:

sampling a first pseudorandom NRZ data stream;

determining a first mean frequency of transitions (Fd1) in the first data stream;

determining a transition probability (P) associated with the first mean frequency of transitions (P);

generating a first reference source frequency responsive to the first mean frequency of transitions;

using a phase/frequency detector responsive to the reference source frequency, the transition probability, and a voltage controlled oscillator frequency;

in response to using the phase/frequency detector, supplying a voltage controlled oscillator tuning voltage; and,

generating a voltage controlled oscillator frequency first reference clock (refclk1) responsive to the tuning voltage.

14. The method of claim 13 further comprising:

storing the first reference source frequency;

in the absence of a NRZ data stream, using the first reference frequency in memory; and,

generating a voltage controlled oscillator frequency holdover clock responsive to the first reference source frequency.

15. The method of claim 14 further comprising:

deriving a first mean data stream rate (B1) from a comparison of the first mean frequency of transitions (Fd1) and the transition probability, where B1 = Fd1/P;

wherein generating a first reference source frequency responsive to the first mean frequency of transitions includes generating a first reference source frequency in response to the first mean data stream rate; and,

wherein using a phase frequency detector responsive to the reference source frequency, the transition probability, and a voltage controlled oscillator frequency includes comparing the first reference source frequency to the VCO frequency.

16. The method of claim 15 further comprising:

multiplying the VCO frequency by P to supply a scaled VCO frequency; and

wherein using a phase/frequency detector responsive to the reference source frequency, the transition probability, and a voltage

controlled oscillator frequency includes comparing the first reference source frequency to the scaled VCO frequency.

18. The method of claim 13 wherein determining the mean frequency of transitions (Fd) in the data stream includes determining the frequency of transitions selected from the group including:

positive transitions having a 0.25 probability of occurrence;

negative transitions having a 0.25 probability of occurrence; and,

both positive and negative transitions having a 0.5 probability of occurrence.

19. The method of claim 13 further comprising:

sampling a second pseudorandom NRZ data stream having a second mean frequency of transitions (Fd2), following the sampling of the first data stream;

deriving the second mean frequency of transitions;

generating a second reference source frequency responsive to the second mean frequency of transitions;

using the phase/frequency detector responsive to the second reference source frequency, the transition probability, and the voltage controlled oscillator frequency;

in response to using the phase/frequency detector, supplying a voltage controlled oscillator tuning voltage;

generating a voltage controlled oscillator output frequency second reference clock (refclk2) responsive to the tuning voltage;

supplying the second reference clock to the clock data recovery circuit; and,

using the second reference clock to acquire the second data stream rate clock.

20. In a communications device integrated circuit (IC), a system for synchronizing a reference clock to a pseudorandom non-return to zero (NRZ) data stream, the system comprising:

a transition detector having an input to sample a pseudorandom NRZ data stream and an output to supply a mean frequency of transitions (Fd);

a probability analyzer to determine the transition probability (P) for the mean frequency of transitions;

a voltage controlled oscillator (VCO) having an input to accept a tuning voltage and an output to supply a voltage controlled oscillator frequency responsive to the tuning voltage; and,

a phase/frequency detector (PFD) responsive to the mean frequency of transitions, the transition probability, and the VCO frequency, the phase/frequency detector having an output to supply the tuning voltage.

21. The system of claim 20 further comprising:

an exclusive-OR (XOR) phase detector having inputs to receive the NRZ data stream and the voltage controlled oscillator frequency, the exclusive-OR phase detector having an output to supply the tuning voltage;

a multiplexer having signal inputs connected to the XOR and phase/frequency detector outputs, a control input to select a signal input, and an output connected to the voltage controlled oscillator input; and,

wherein the multiplexer selects the phase/frequency detector output to acquire the NRZ data stream, and selects the XOR phase detector output to track the NRZ data stream, after acquisition.

22. The system of claim 21 wherein the probability analyzer has an input to receive the VCO frequency, the probability analyzer multiplying the VCO frequency by P to supply a scaled VCO frequency at an output; and,

wherein the phase/frequency detector has a first input connected to the output of the transition detector to accept the mean frequency of transitions (Fd) and a second input connected to the output of the probability analyzer to accept the scaled VCO frequency.

23. The method of claim 21 wherein the probability analyzer has an input to receive mean frequency of transitions from the transition detector, the probability analyzer comparing the mean frequency of transitions to the transition probability to supply a mean data stream rate (B) at an output, where B = Fd/P; and,

wherein the phase/frequency detector has a first input connected to the output of the probability analyzer to accept the mean data stream rate and a second input connected to the output of the VCO to accept the VCO frequency.

24. The system of claim 21 wherein the transition detector determines a mean frequency of transitions (Fd) in the data stream selected from the group including:

positive transitions having a 0.25 probability of occurrence;

negative transitions having a 0.25 probability of occurrence; and,

both positive and negative transitions having a 0.5 probability of occurrence.

25. The system of claim 21 wherein the transition detector samples n data bits and determines a mean frequency of transitions with a standard deviation as follows:

$$\sigma = \mathrm{SQRT}((P)(1 - P)(n)).$$

26. In a communications device integrated circuit (IC), a system for synchronizing a reference clock to a pseudorandom non-return to zero (NRZ) data stream, the system comprising:

a transition detector having an input to sample a pseudorandom NRZ data stream and an output to supply a mean frequency of transitions (Fd);

a gating circuit having an output to supply a gate time period (Td);

a probability analyzer having an input to receive the mean frequency of transitions and an input to accept the gate time period, the probability analyzer comparing a transition count of the mean frequency

of transitions to a transition probability (P) and supplying a compensated transition count at an output;

a decoder having an input to accept the compensated transition count, the decoder determining a frequency range corresponding to the compensated transition count and supplying a frequency range selection command at an output;

a phase/frequency detector (PFD) responsive to the mean frequency of transitions, the transition probability, and the VCO frequency, the phase/frequency detector having an output to supply the tuning voltage; and,

a multiband voltage controlled oscillator (VCO) having an input to accept a tuning voltage, an input to accept the frequency range selection command, and an output to supply a voltage controlled oscillator frequency responsive to the tuning voltage and frequency range selection.

27. The system of claim 26 further comprising:

an exclusive-OR (XOR) phase detector having inputs to receive the NRZ data stream and the voltage controlled oscillator frequency, the exclusive-OR phase detector having an output to supply the tuning voltage;

a multiplexer having signal inputs connected to the XOR and phase/frequency detector outputs, a control input to select a signal input, and an output connected to the voltage controlled oscillator input; and,

wherein the multiplexer selects the phase/frequency detector output to acquire the NRZ data stream, and selects the XOR phase detector output to track the NRZ data stream, after acquisition.

28. The system of claim 27 wherein the probability analyzer has an input to receive the VCO frequency, the probability analyzer supplying the VCO frequency multiplied by P at an output; and,

wherein the phase/frequency detector has a first input connected to the output of the transition detector to accept the mean frequency of transitions (Fd) and a second input connected to the output of the probability analyzer to accept the scaled VCO frequency.

29. The method of claim 27 wherein the probability analyzer has an input to receive mean frequency of transitions from the transition detector, the probability analyzer comparing the mean frequency of transitions to the transition probability to supply a mean data stream rate (B) at an output, where B = Fd/P; and,

wherein the phase/frequency detector has a first input connected to the output of the probability analyzer to accept the mean data stream rate and a second input connected to the output of the VCO to accept the VCO frequency.

30. The system of claim 27 wherein the transition detector determines a mean frequency of transitions (Fd) in the data stream selected from the group including:

positive transitions having a 0.25 probability of occurrence;

negative transitions having a 0.25 probability of occurrence; and,

both positive and negative transitions having a 0.5 probability of occurrence.

31. The system of claim 27 wherein the transition detector samples n data bits and determines a mean frequency of transitions with a standard deviation as follows:

$$\sigma = \mathrm{SQRT}((P)(1 - P)(n)).$$

32. A system for generating a reference clock in the absence of a pseudorandom non-return to zero (NRZ) data stream, the system comprising:

a transition detector having an input to sample a first pseudorandom NRZ data stream and an output to supply a first mean frequency of transitions (Fd1);

a probability analyzer to determine the transition probability (P) associated with the first mean frequency of transitions;

a voltage controlled oscillator (VCO) having an input to accept a tuning voltage and an output to supply a voltage controlled oscillator frequency first reference clock (refclk1) responsive to the tuning voltage;

a reference source having a first frequency output responsive to the first mean frequency of transitions;

a phase/frequency detector (PFD) responsive to the first frequency, the transition probability, and the VCO frequency, the

phase/frequency detector having an output to supply the tuning voltage; and,

a clock data recovery (CDR) unit having an input to receive the NRZ data stream and an input to receive the first reference clock for use in the absence of the NRZ data stream.

33. The system of claim 32 wherein the transition detector fails to supply a first mean frequency of transitions in the absence of the first data stream;

wherein the reference source has a memory to store the first frequency, and supplies the first frequency in the absence of the first mean frequency of transitions; and,

wherein the voltage controlled oscillator generates a holdover clock responsive to the first reference.

34. The system of claim 32 wherein the probability analyzer has an input to accept the first mean frequency of transitions and an output to supply a first mean data stream rate (B1) from the comparison of the first mean frequency of transitions (Fd1) and the transition probability, where B1 = Fd1/P;

wherein the reference source has an input connected to the probability analyzer output to supply a first frequency responsive to the first mean data stream rate; and,

wherein the phase/frequency detector has a first input to receive the first frequency and a second input to receive the VCO frequency.

35. The system of claim 33 wherein the probability analyzer has an input to accept the VCO frequency, the probability analyzer multiplying the VCO frequency by P to supply a scaled VCO frequency at an output;

wherein the reference source has an input connected to the transition detector to supply a first frequency responsive to the first mean frequency of transitions; and,

wherein the phase frequency detector has a first input to receive the first frequency and a second input to receive the scaled VCO frequency.

36. The system of claim 32 wherein the transition detector determines a mean frequency of transitions (Fd) in the data stream selected from the group including:

positive transitions having a 0.25 probability of occurrence;

negative transitions having a 0.25 probability of occurrence; and,

both positive and negative transitions having a 0.5 probability of occurrence.

37. The system of claim 32 wherein the transition detector samples n data bits and determines a mean frequency of transitions with a standard deviation as follows:

$$\sigma = \mathrm{SQRT}((P)(1 - P)(n)).$$

38. The system of claim 32 wherein the transition detector samples a second pseudorandom NRZ data stream having a second mean frequency of transitions (Fd2), following the sampling of the first data stream and derives the second mean frequency of transitions;

wherein the reference source generates a second frequency responsive to the second mean frequency of transitions;

wherein the phase/frequency detector is responsive to the second reference source frequency, the transition probability, and the voltage controlled oscillator frequency;

wherein the VCO generates a voltage controlled oscillator output frequency second reference clock (refclk2); and,

wherein the CDR uses the second reference clock to acquire the second data stream rate clock.